pH CURVES & INDICATORS

T08D07

How pH indicators work

methyl orange

phenolphthalein

Choosing an appropriate indicator

pH curves

SUMMARY

strong acid strong base

strong acid weak base

weak acid strong base

weak acid weak base

diprotic acid

$H_2C_2O_4$ / NaOH

diprotic base

Na_2CO_3 / HCl

INDICATORS

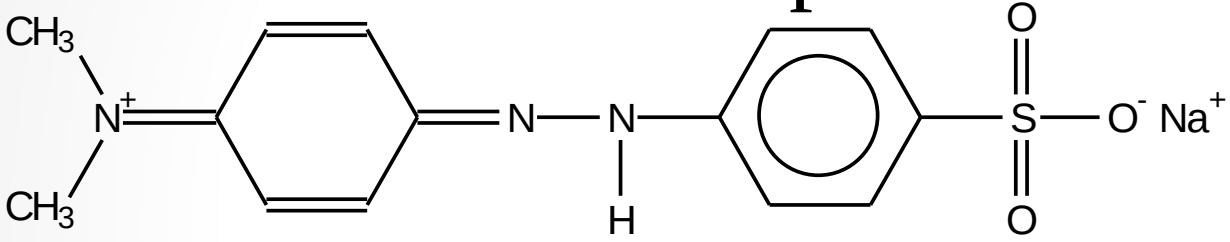
Indicators are weak acids which have a different colour to their conjugate base

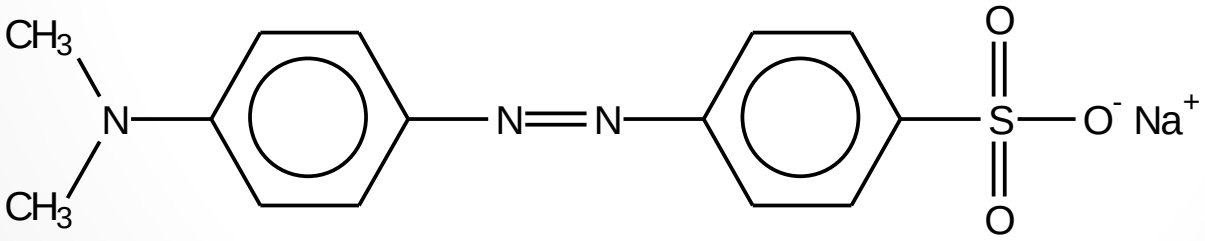
low pH: equilibrium pushed left = color 1

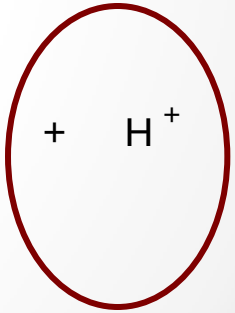
high pH: equilibrium pushed right = color 2

Methyl orange

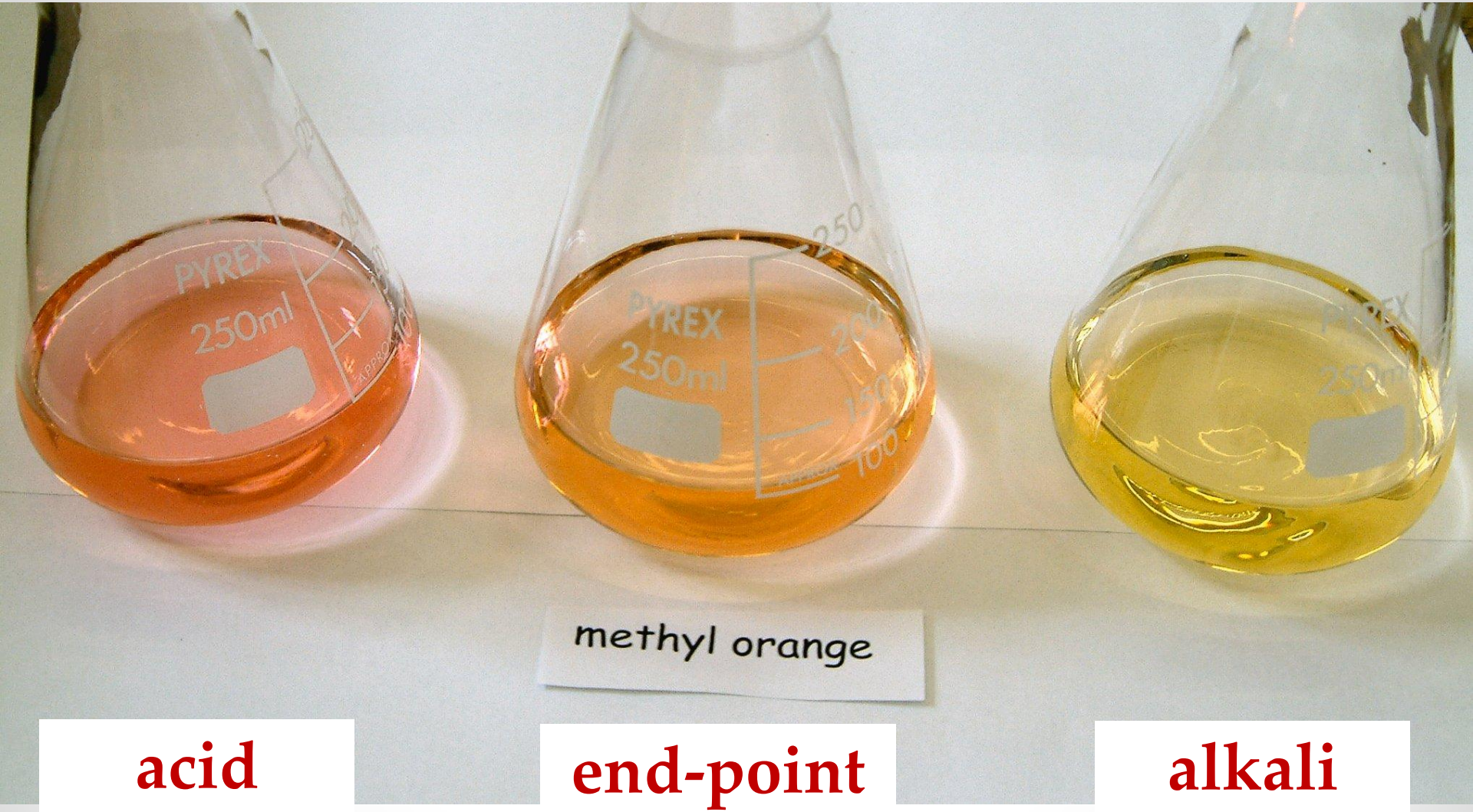
pH < 3.2





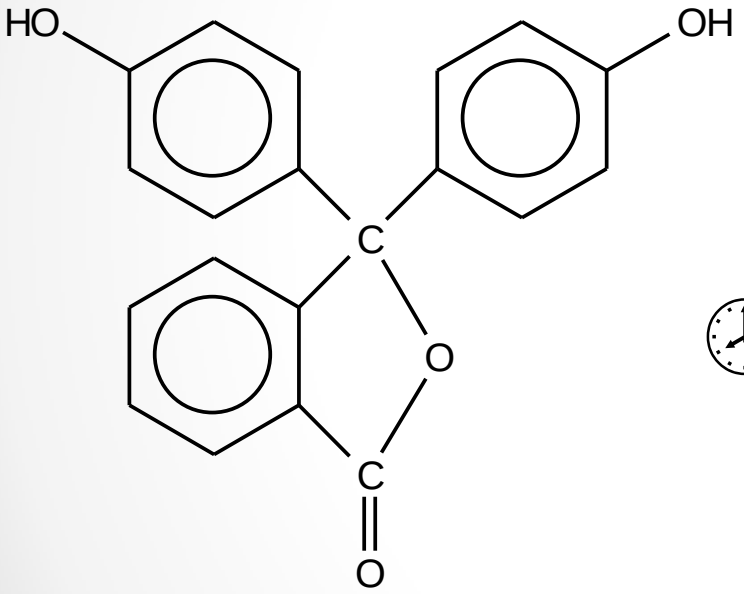


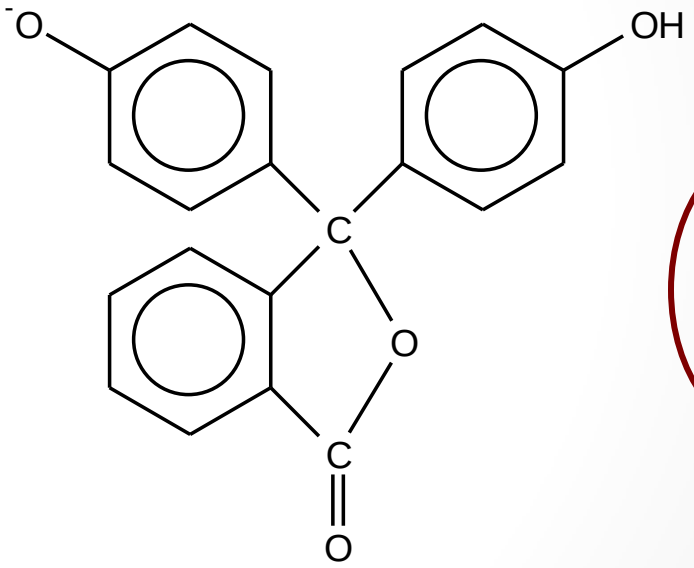
pH > 4.4

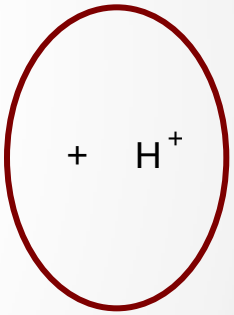


acid **end-point** **alkali**

Phenolphthalein

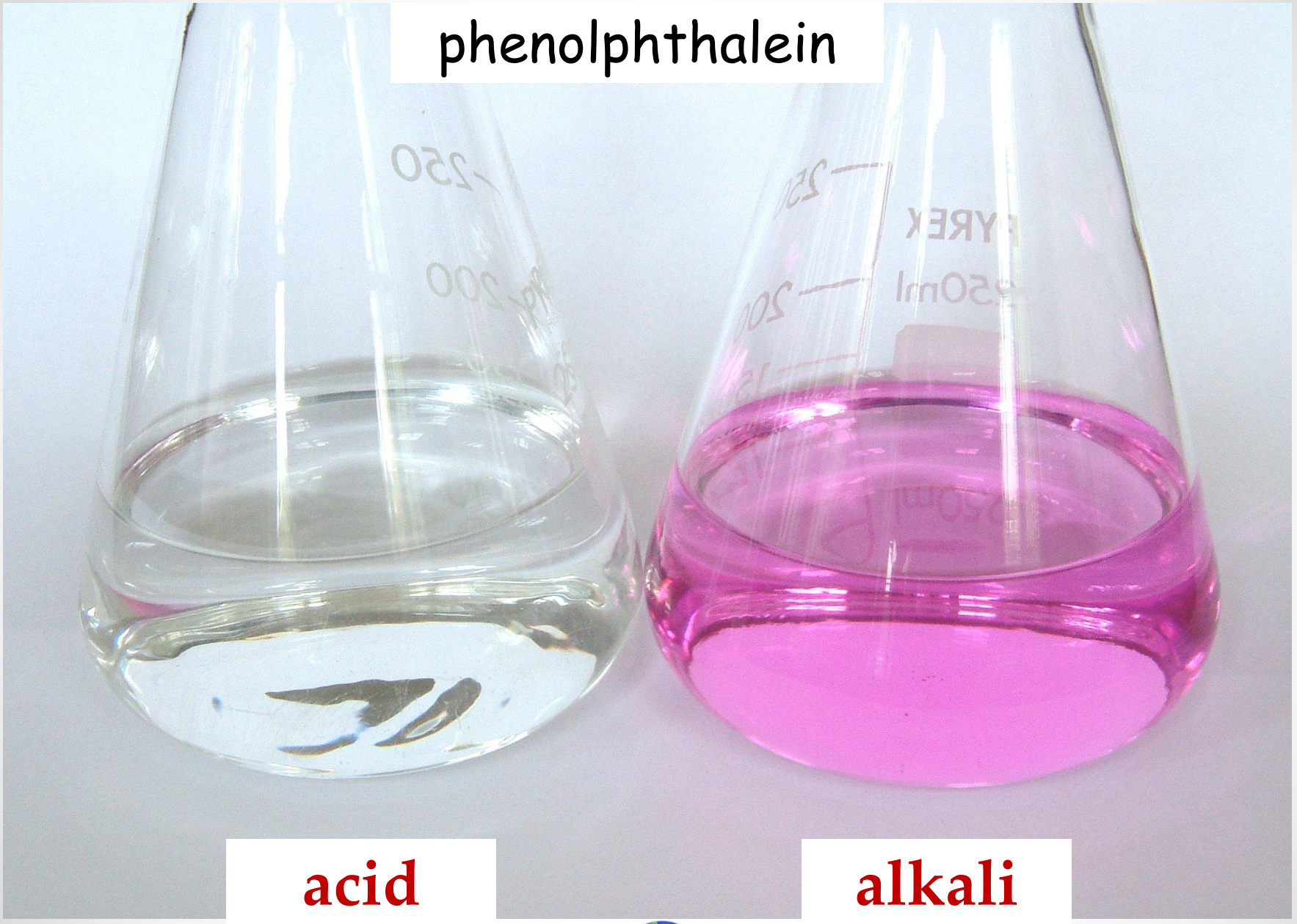






pH < 8.2

pH > 10.0


phenolphthalein
acid
alkali

INDICATORS

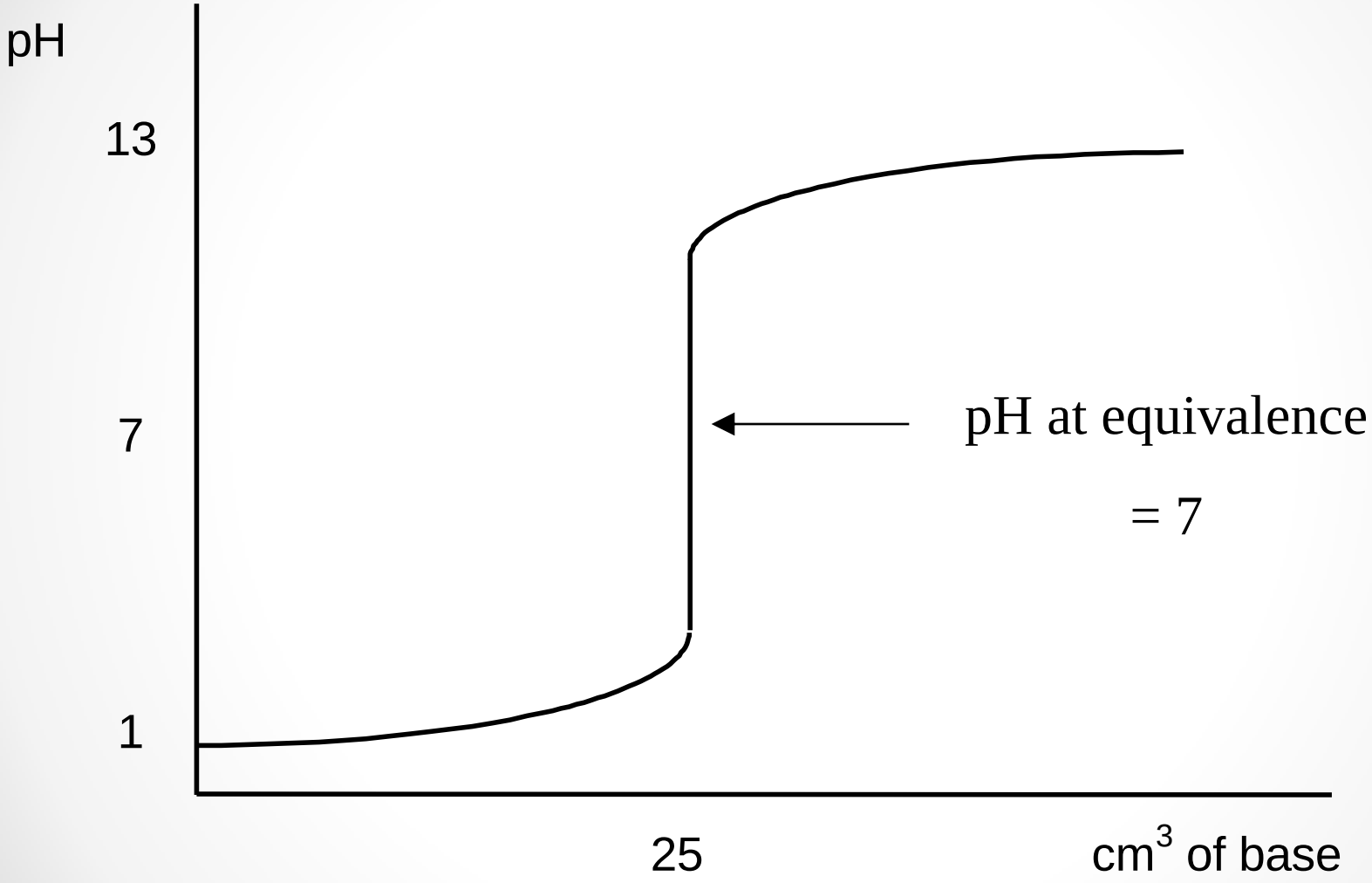
For an indicator to work in a titration:

The pH range of the indicator's color change must be within the range of the pH change at the end-point.

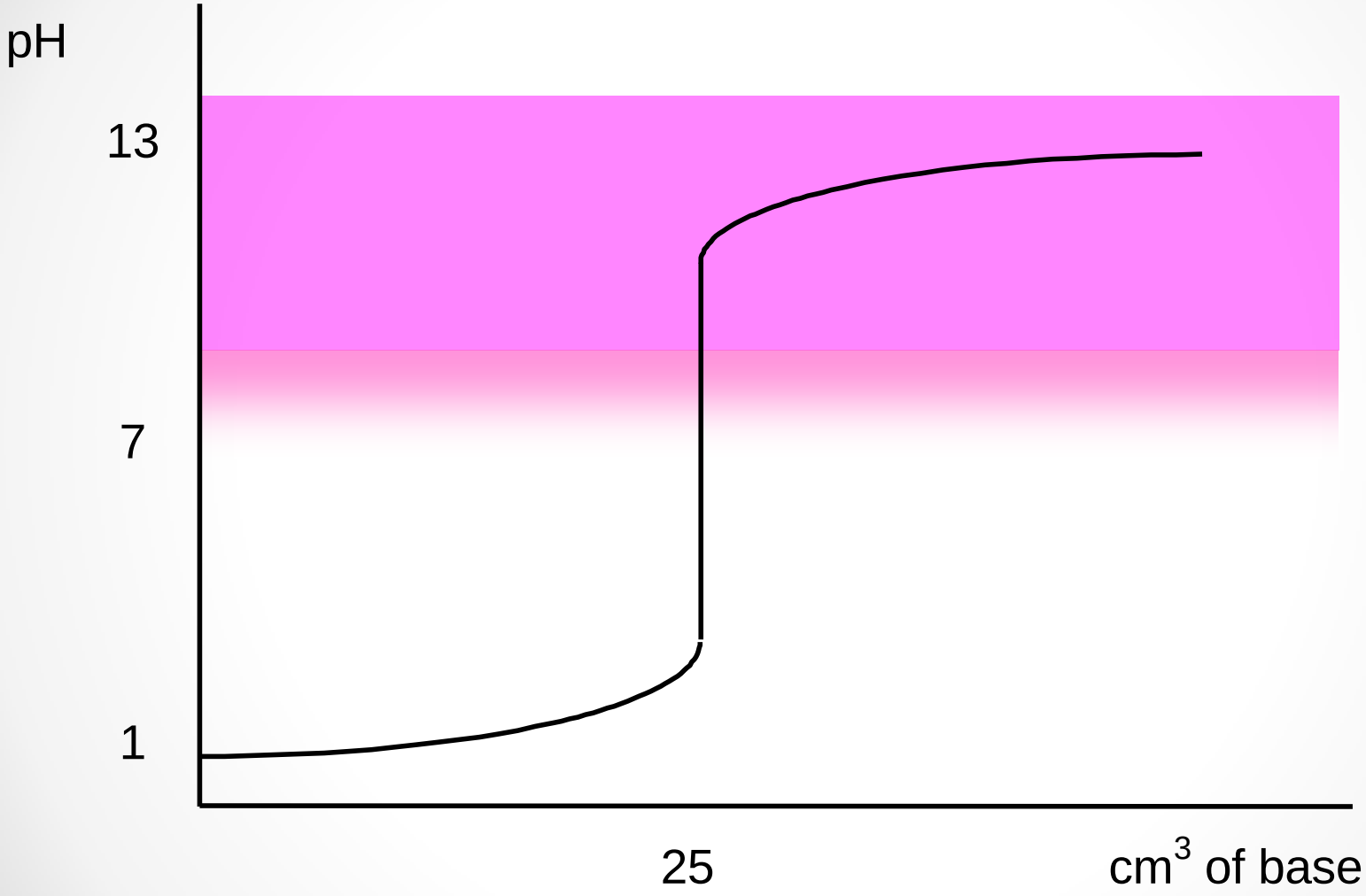
INDICATORS

Indicator	color at low pH	pH range of color change	color at high pH
methyl orange	red	3.2 – 4.4	orange
phenolphthalein	colorless	8.2 – 10.0	purple

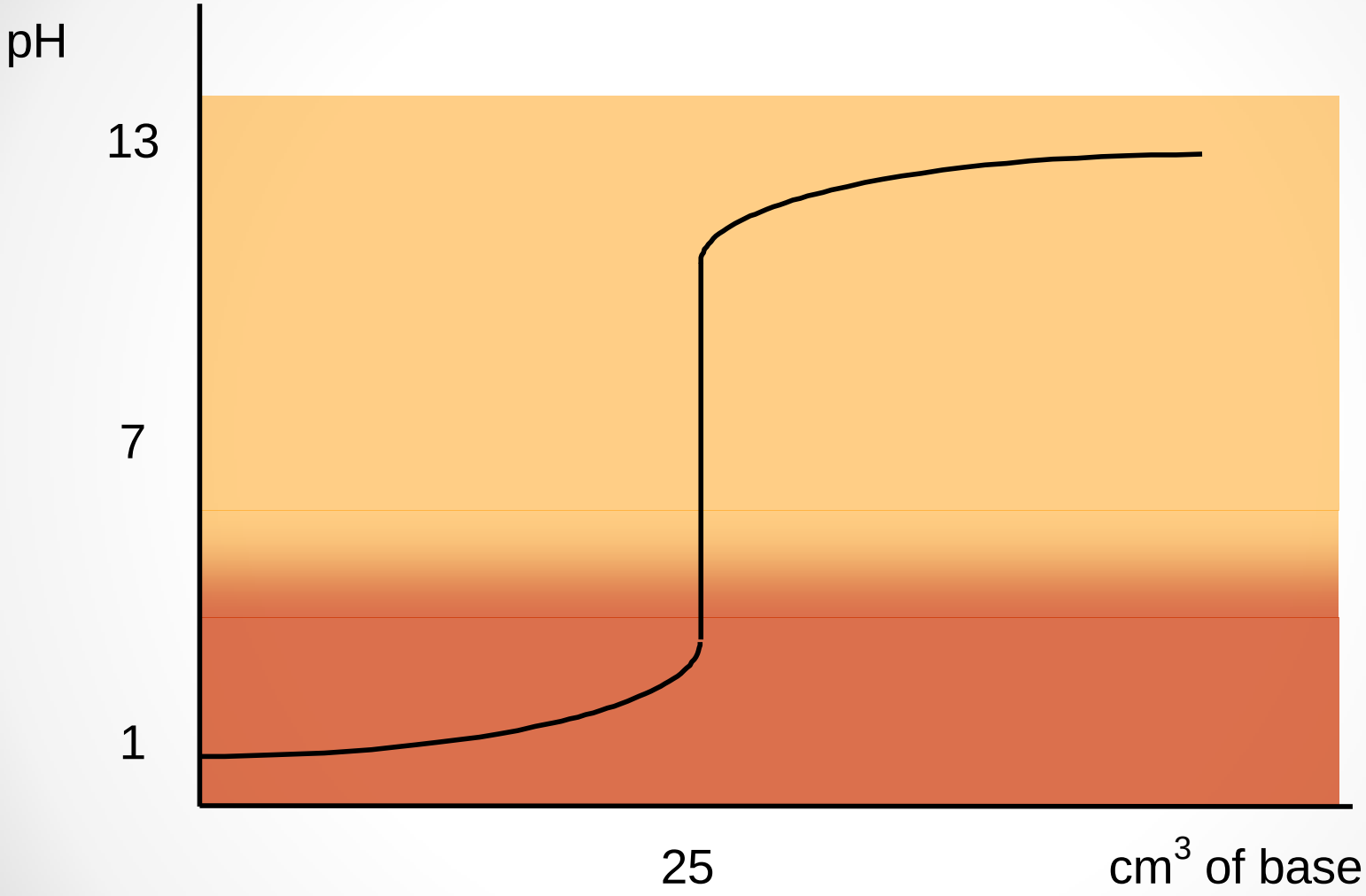
Strong acid – Strong base



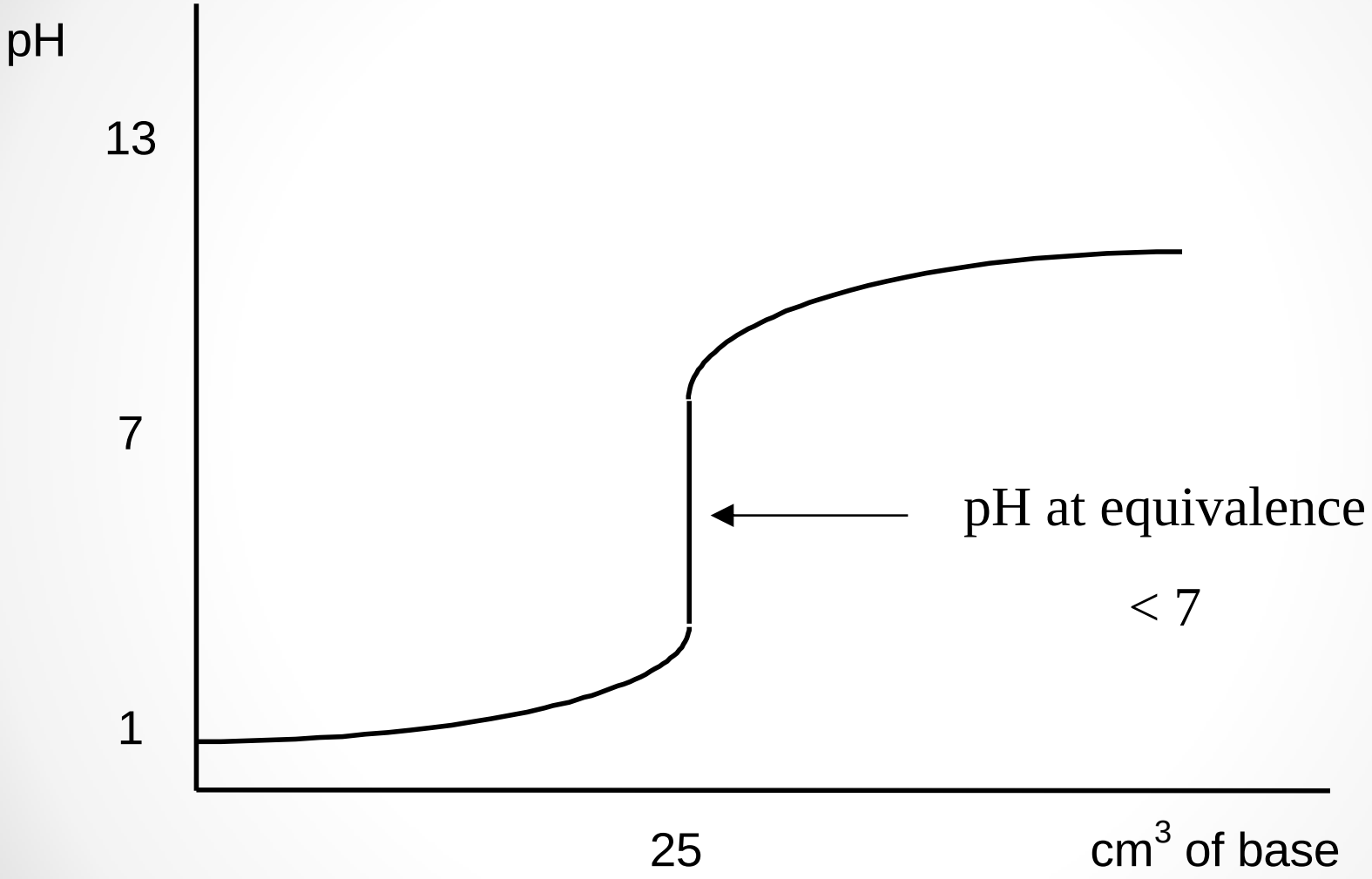
Strong acid – Strong base



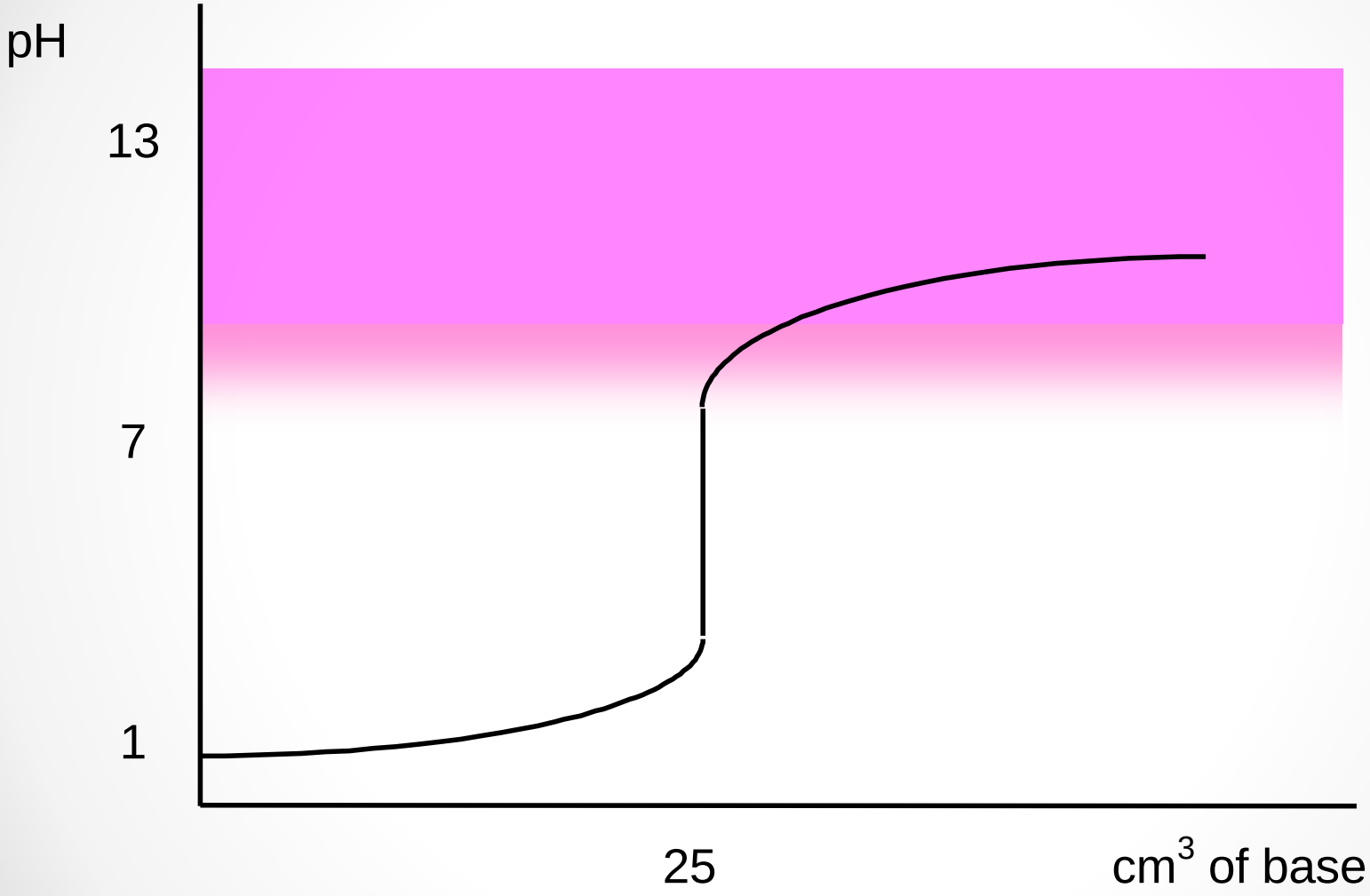
Strong acid – Strong base



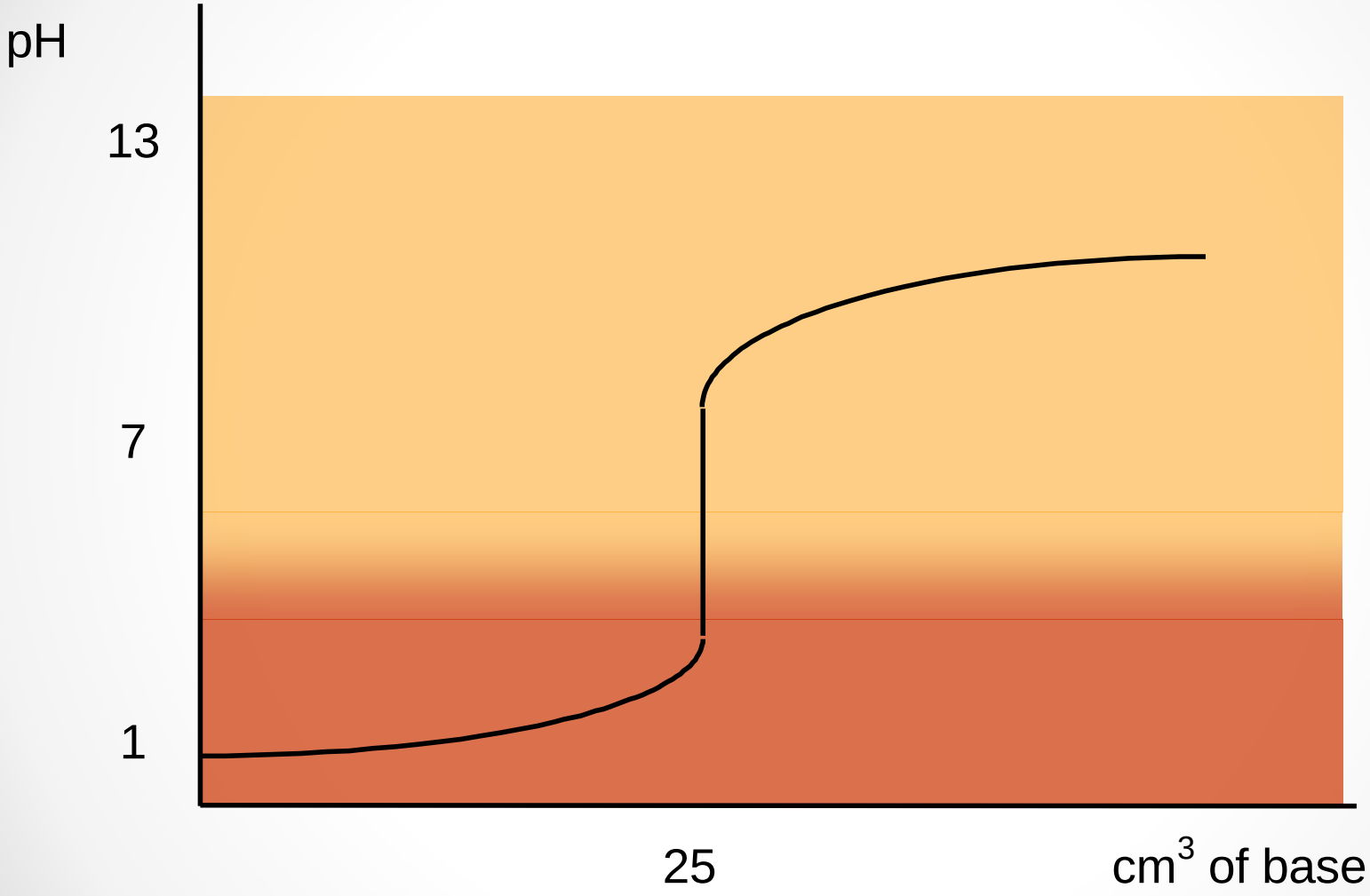
Strong acid – Weak base



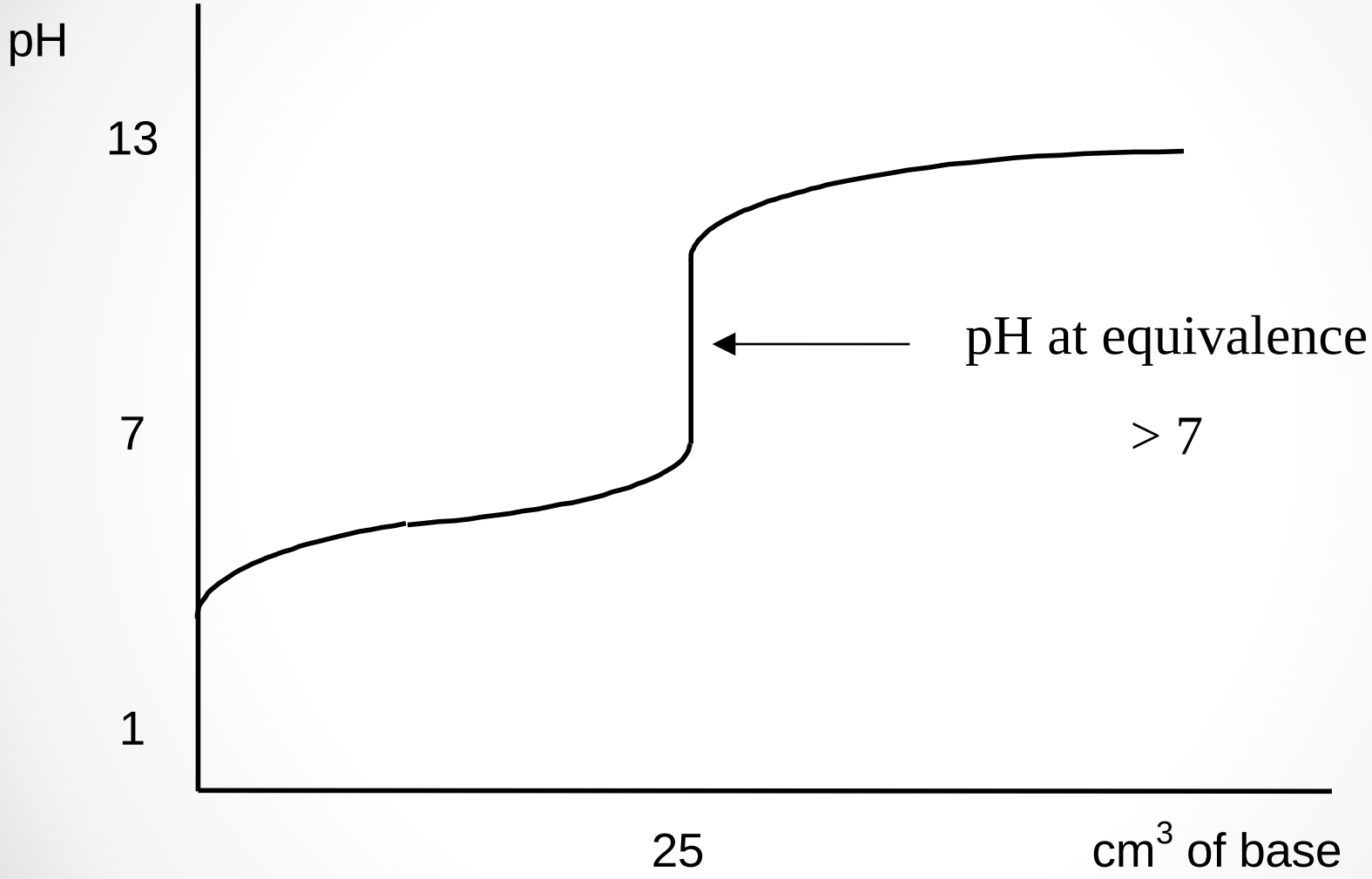
Strong acid – Weak base



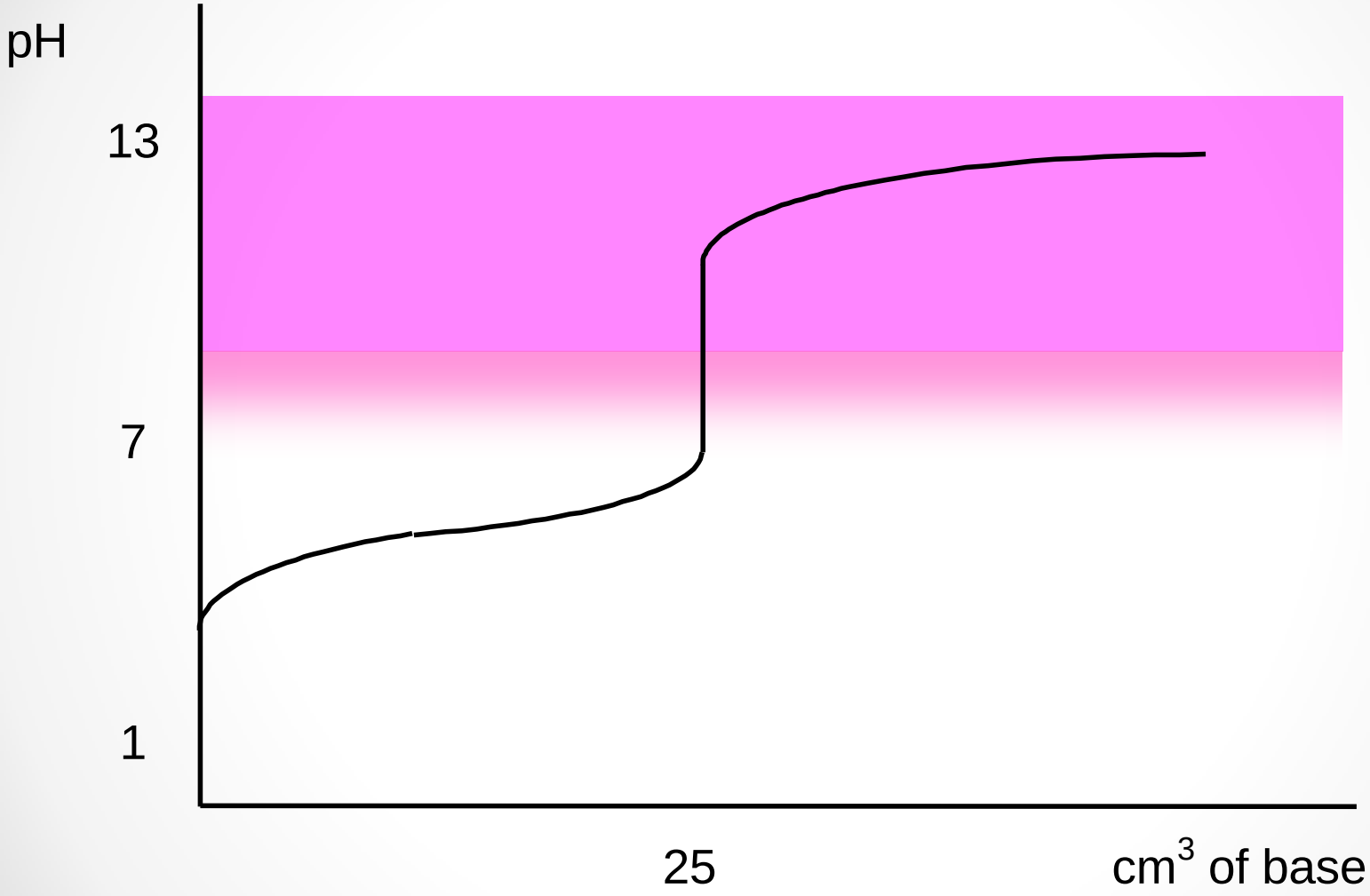
Strong acid – Weak base



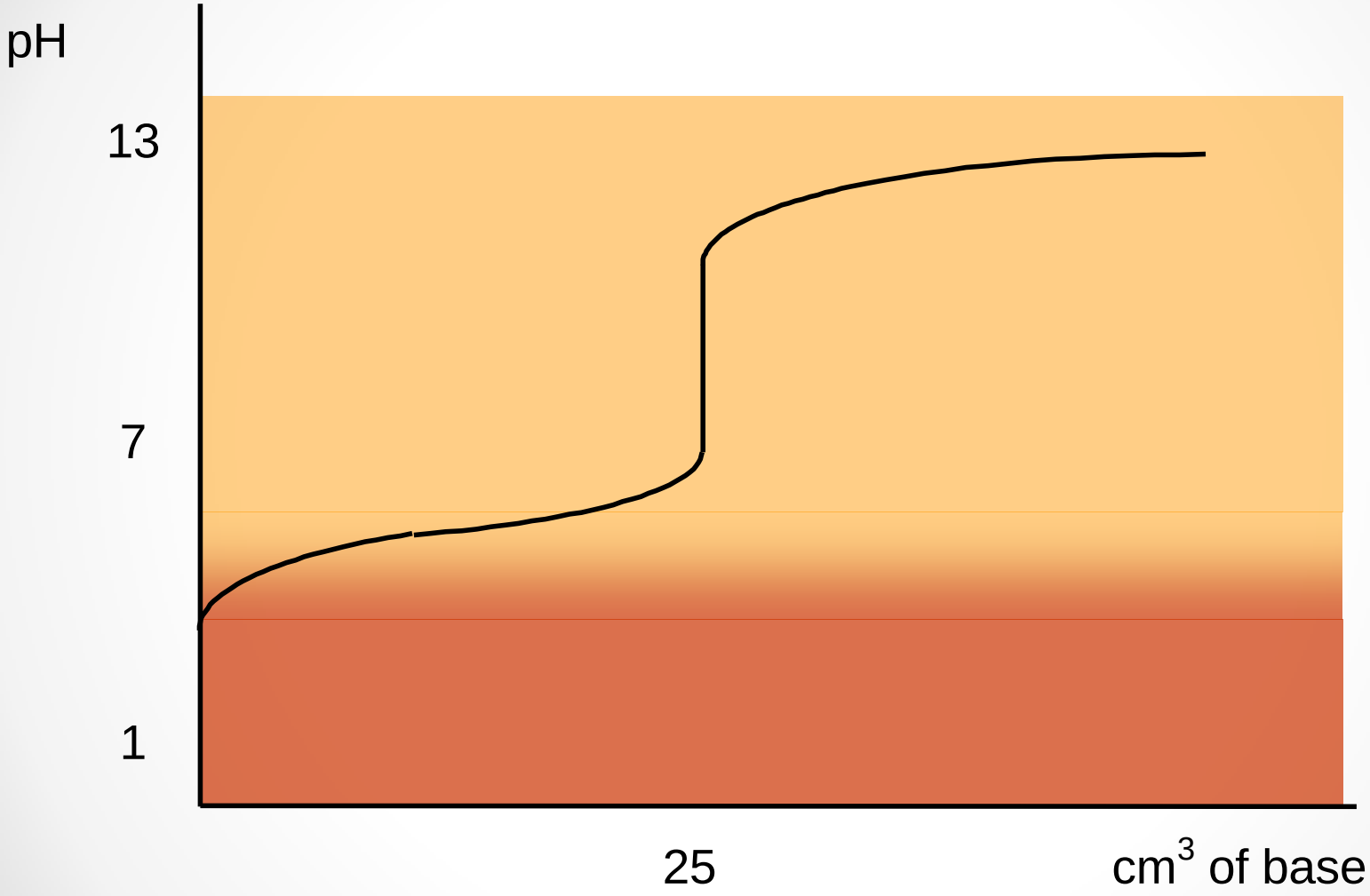
Weak acid – Strong base



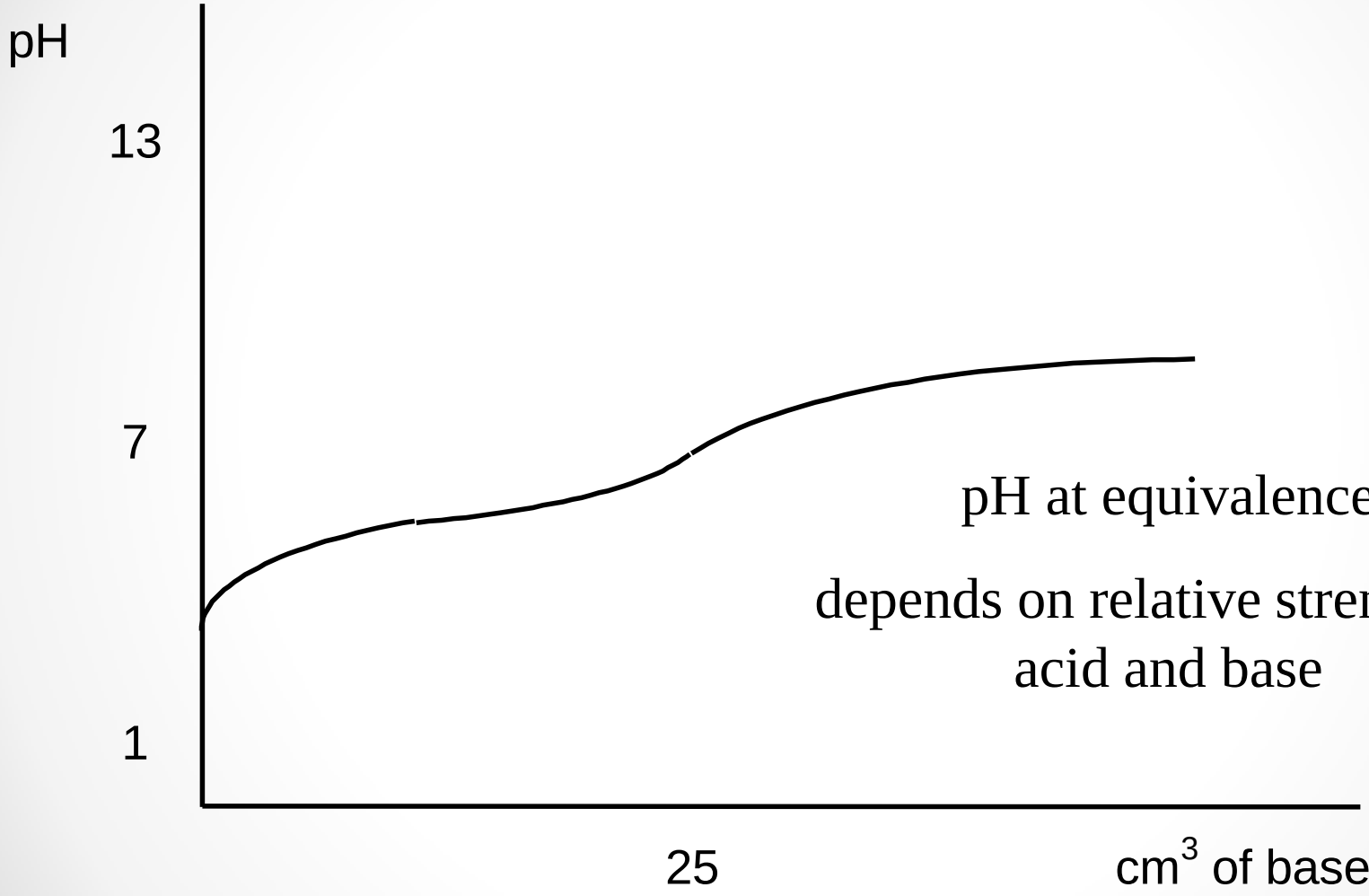
Weak acid – Strong base



Weak acid – Strong base



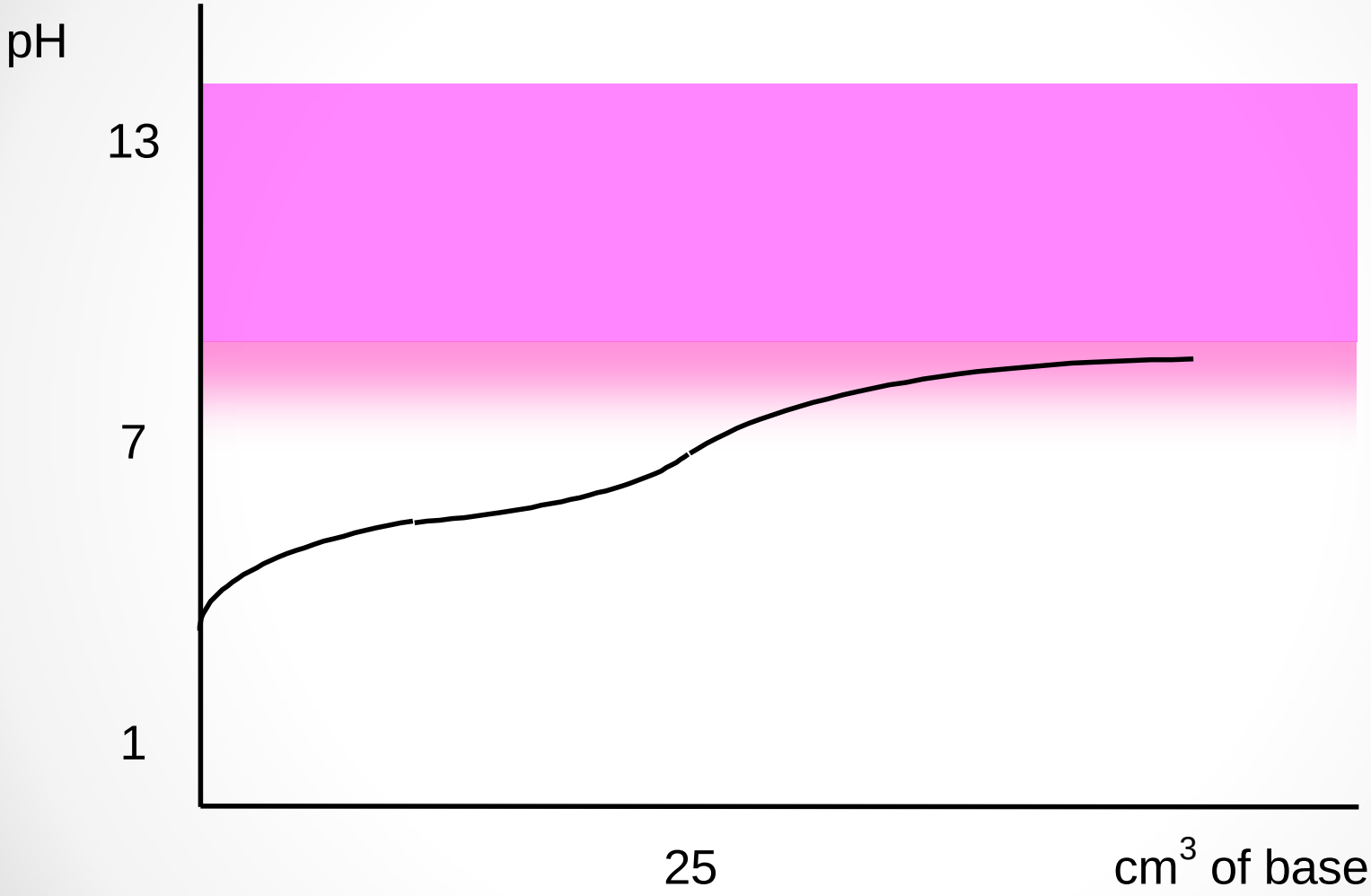
Weak acid – Weak base



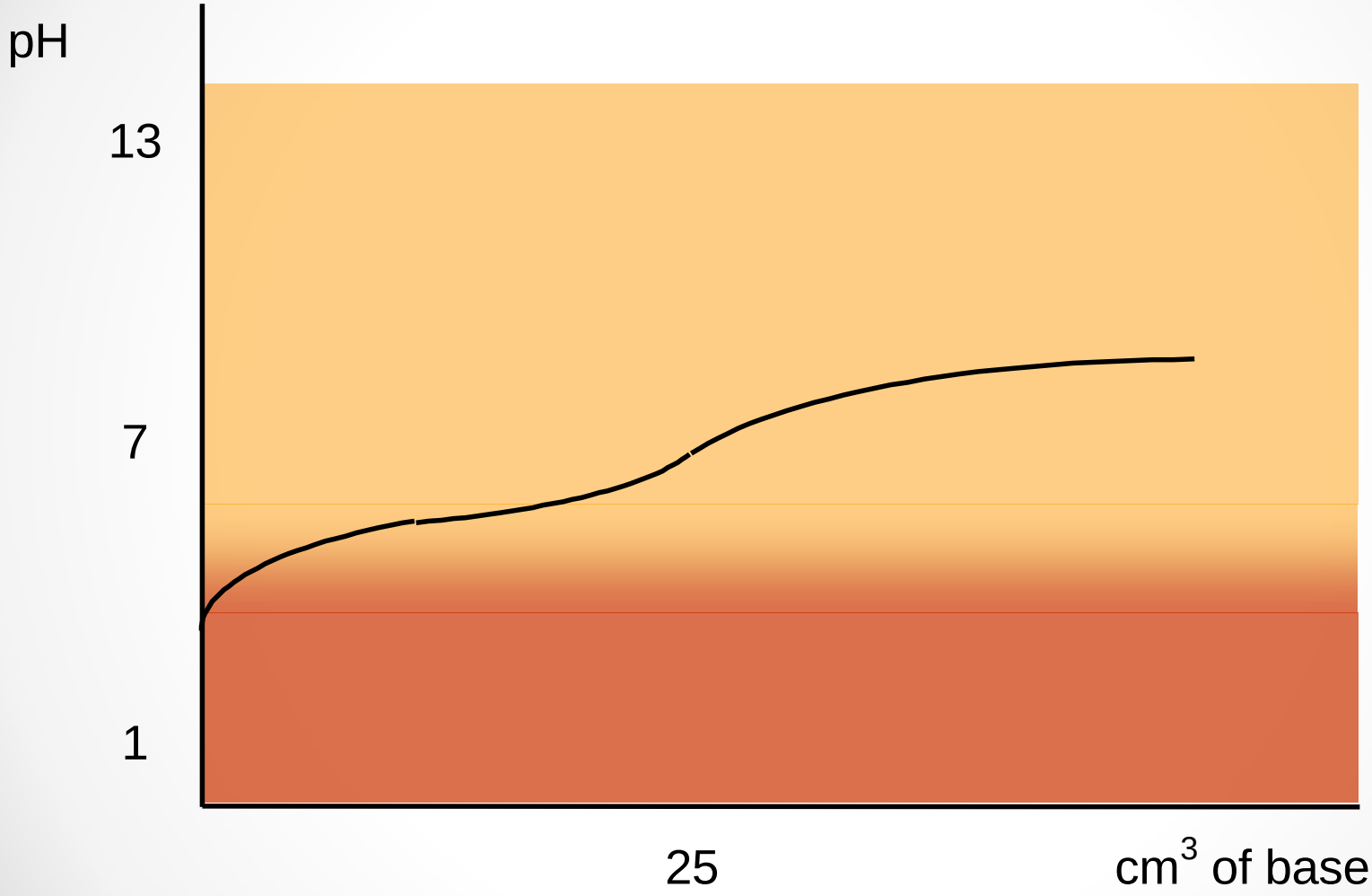
pH at equivalence

depends on relative strength of acid and base

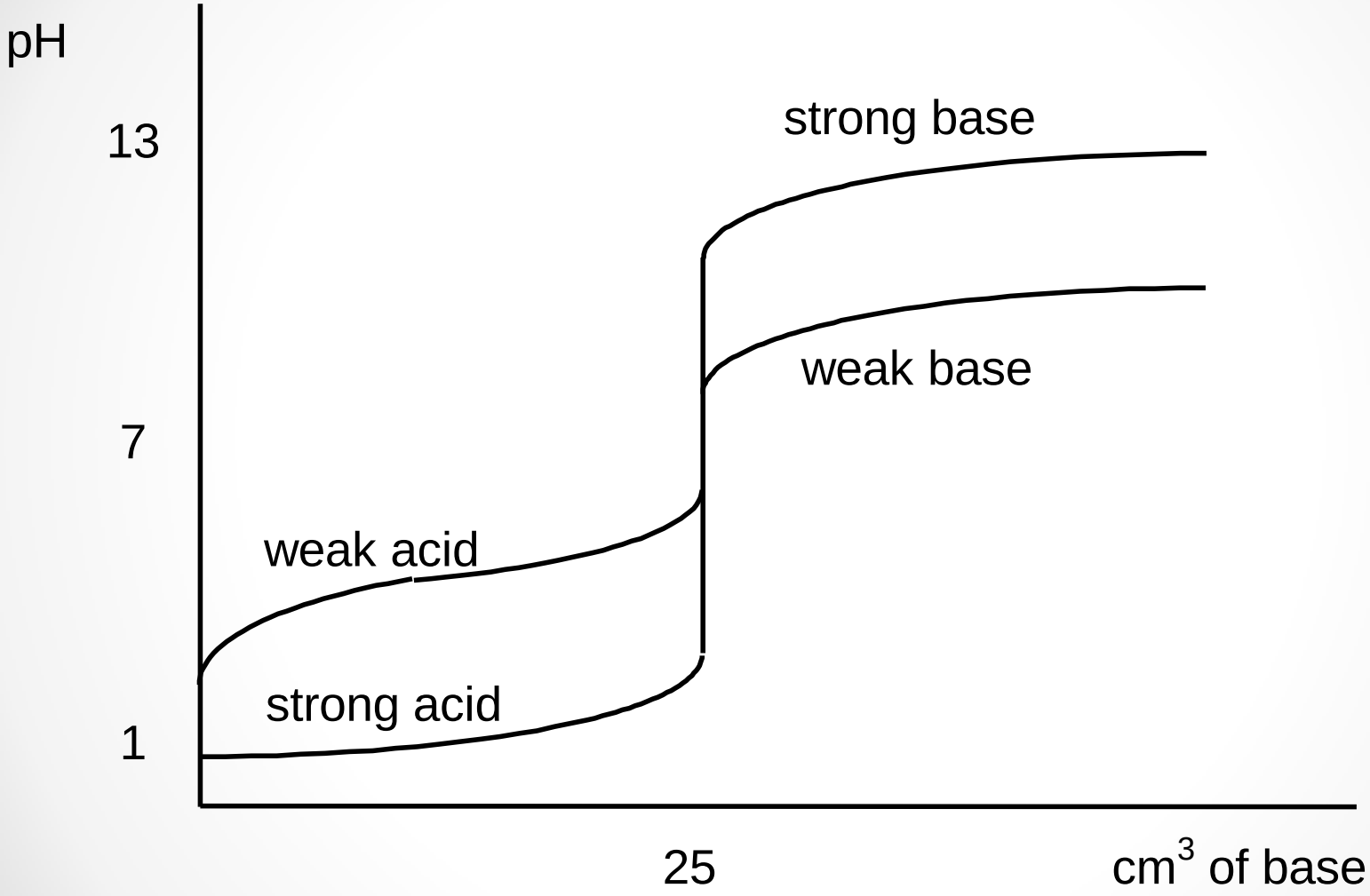
Weak acid – Weak base



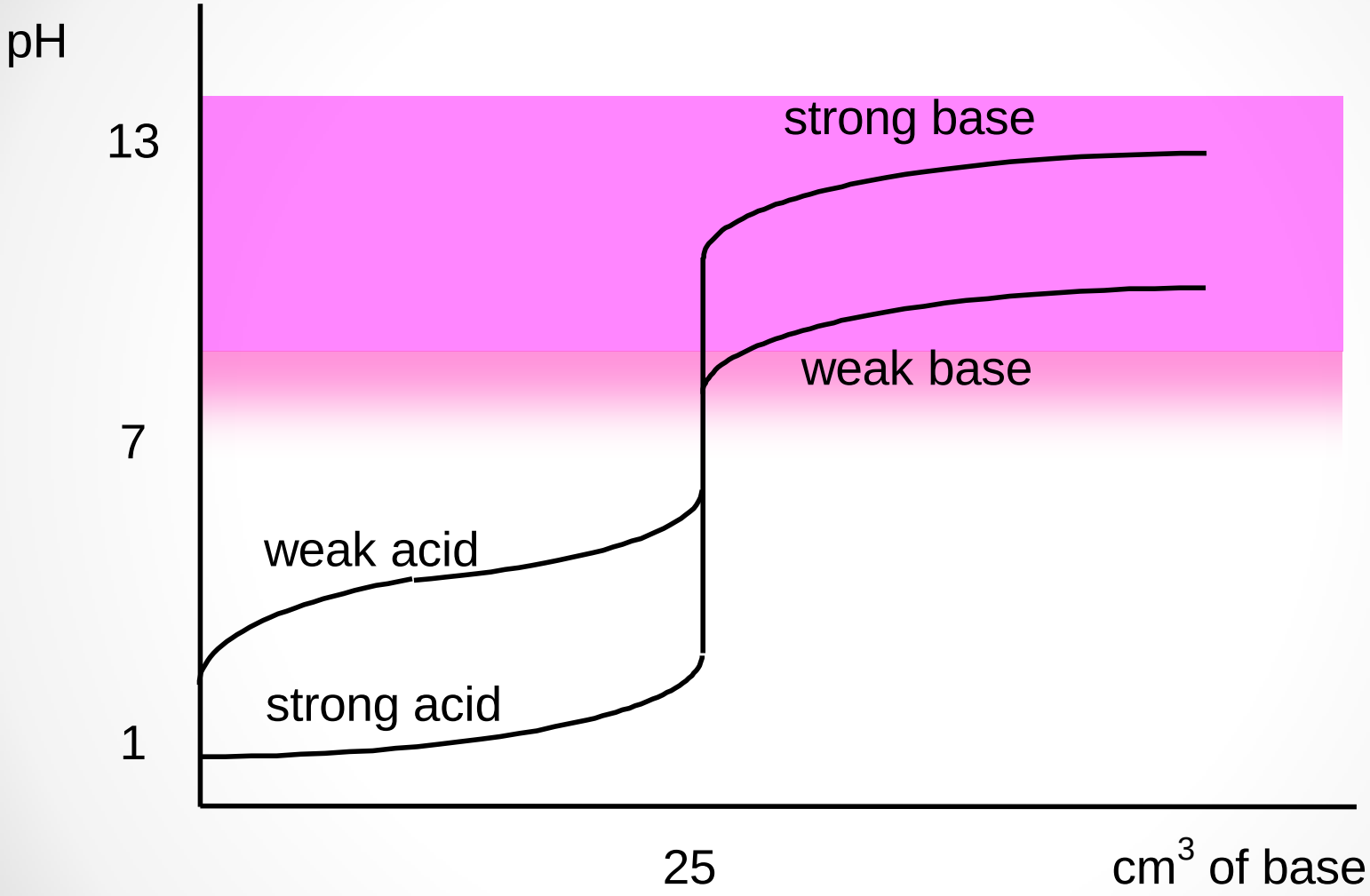
Weak acid – Weak base



SUMMARY


pH
13
7
1
strong base
weak base
weak acid
strong acid
25
cm3 of base

SUMMARY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strong acid
25
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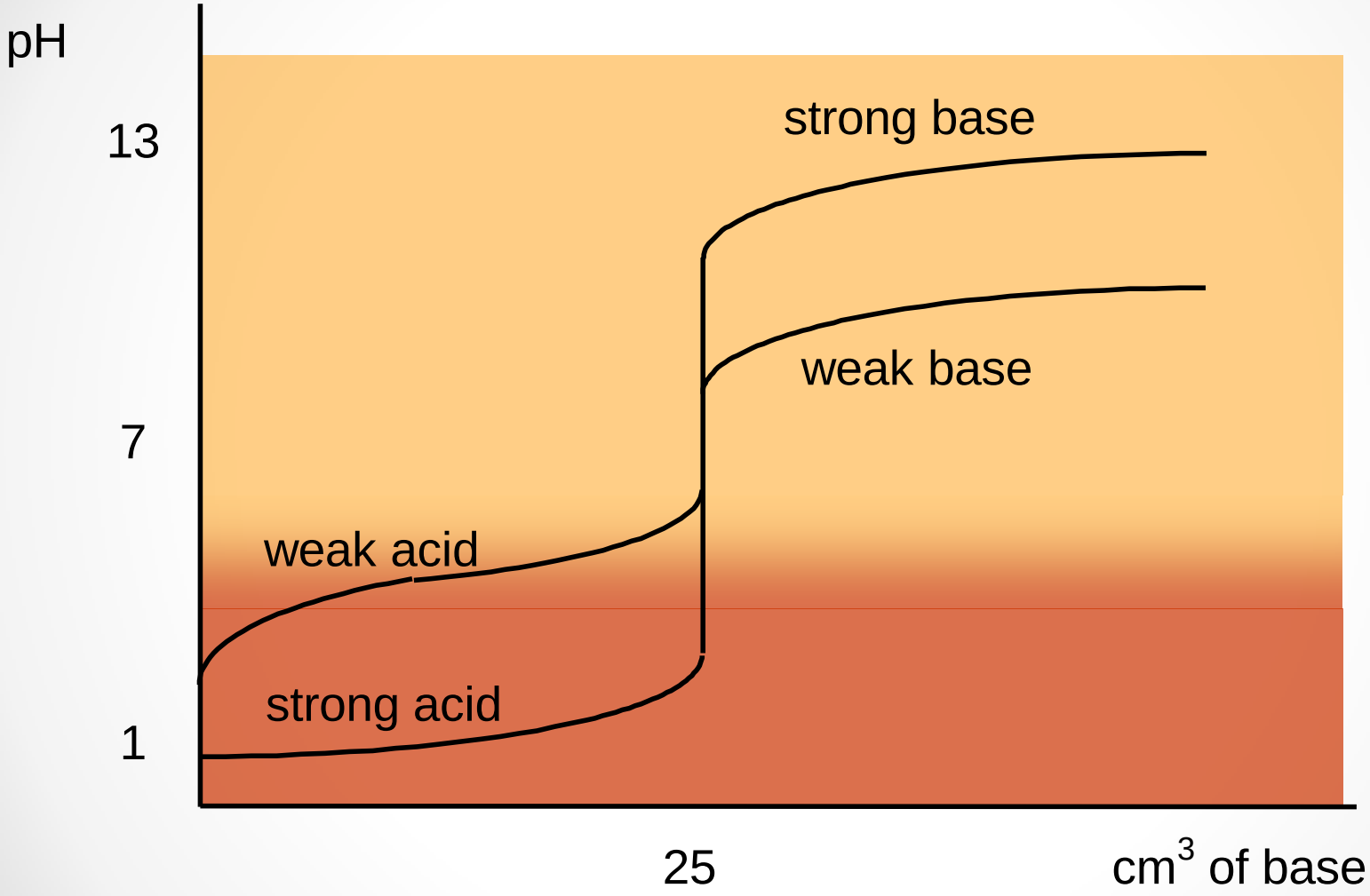
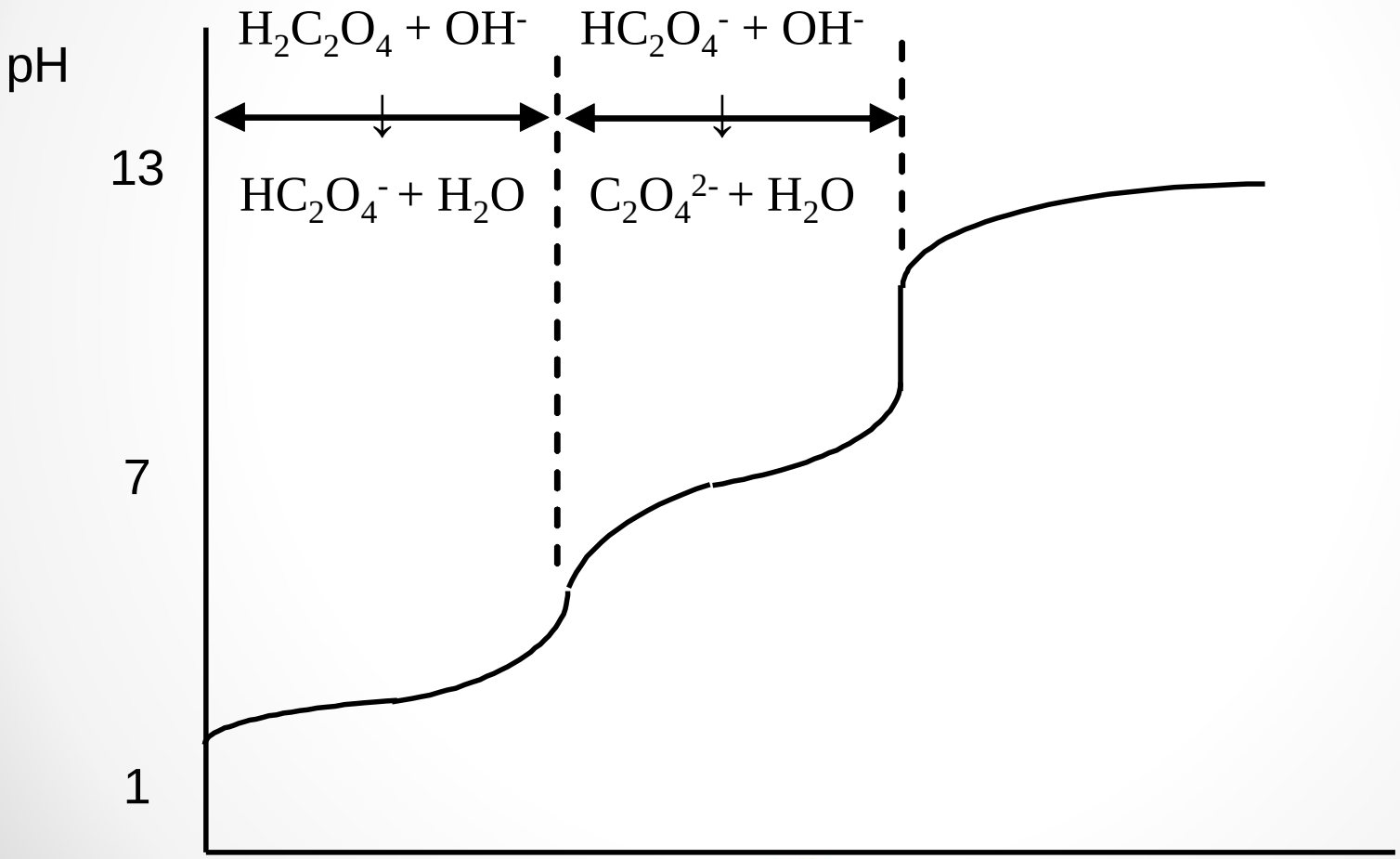
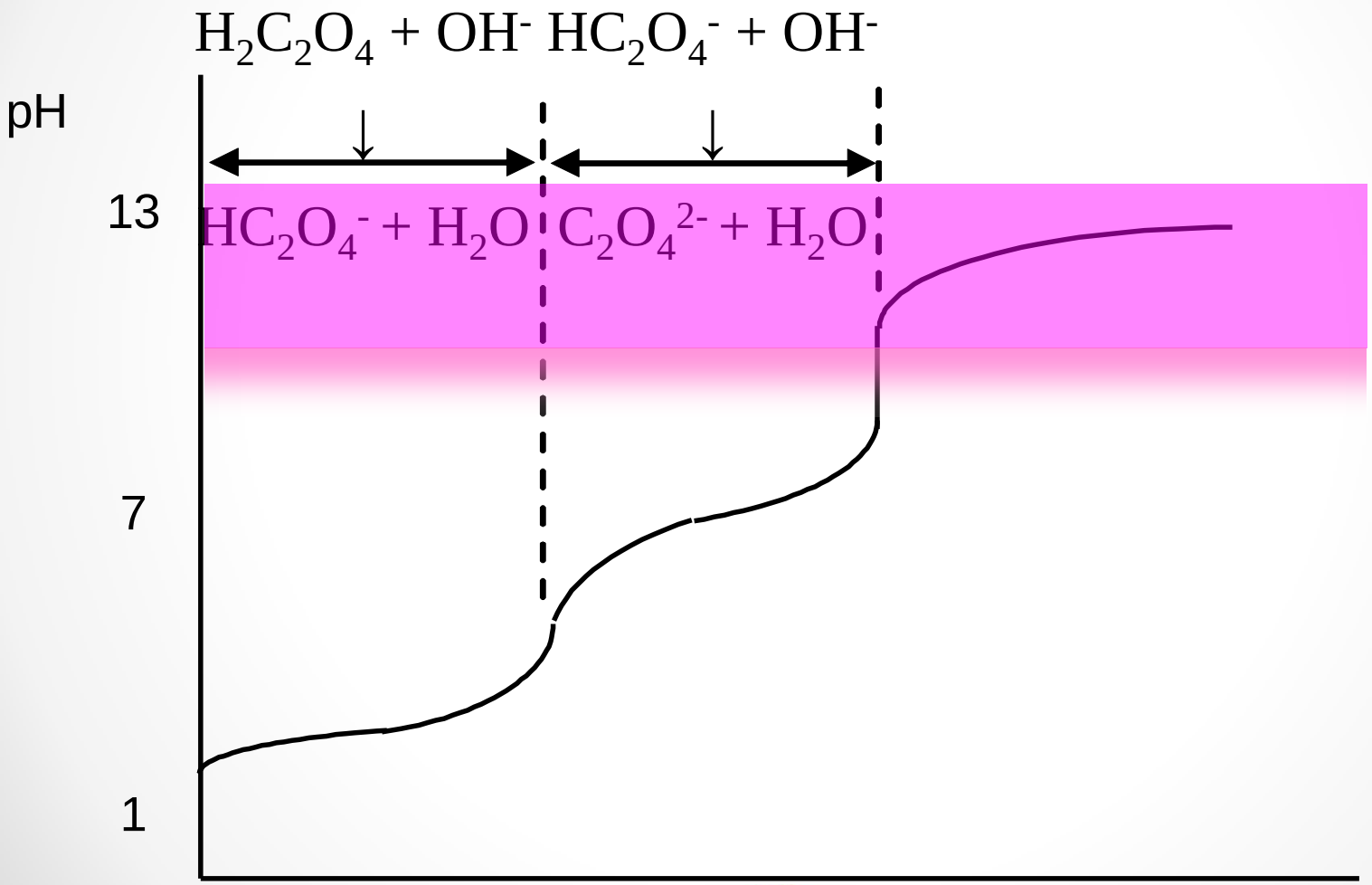

pH
13
7
1
strong base
weak base
weak acid
strong acid
25
cm3 of base

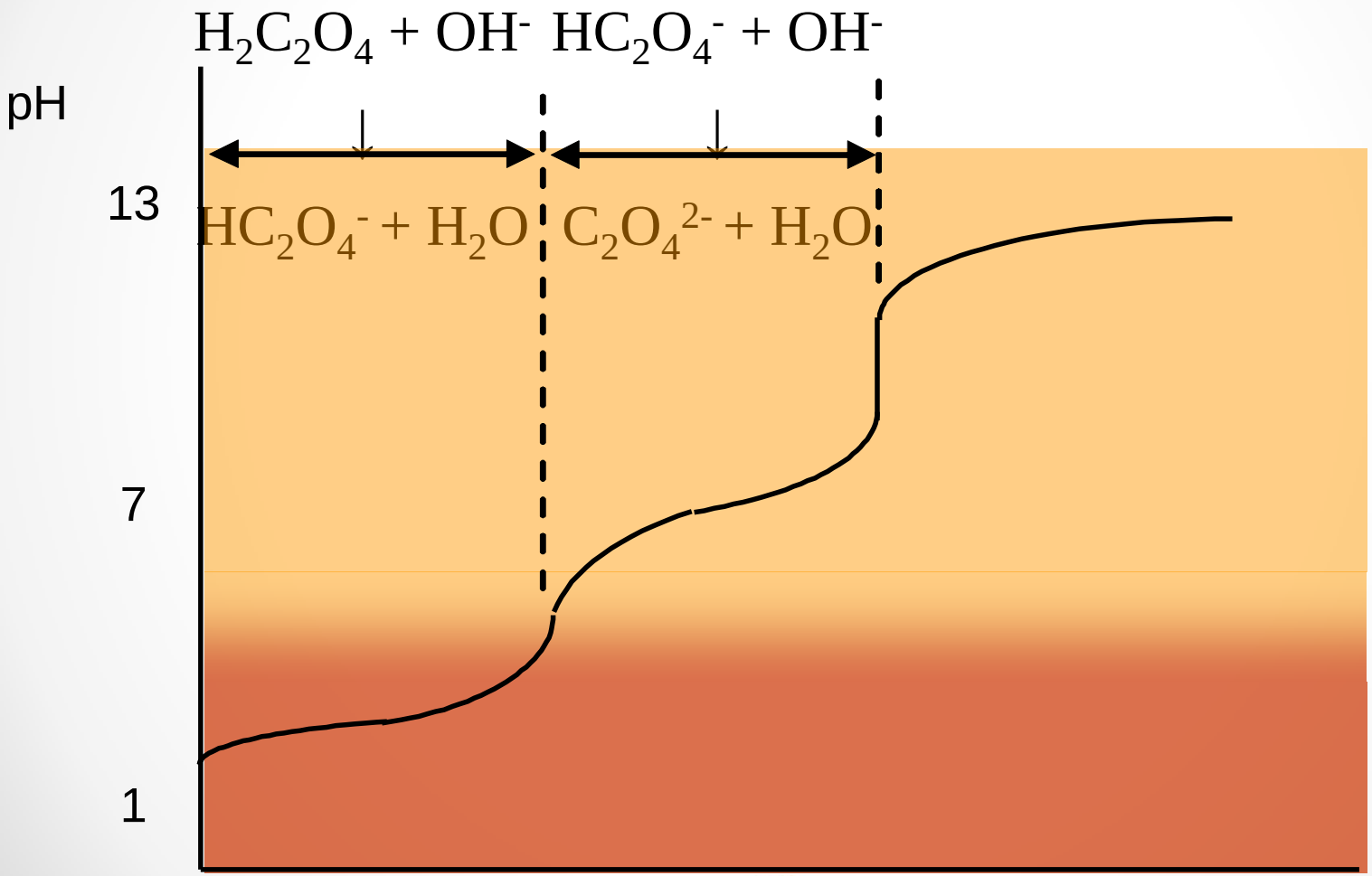
$H_2C_2O_4$ v NaOH



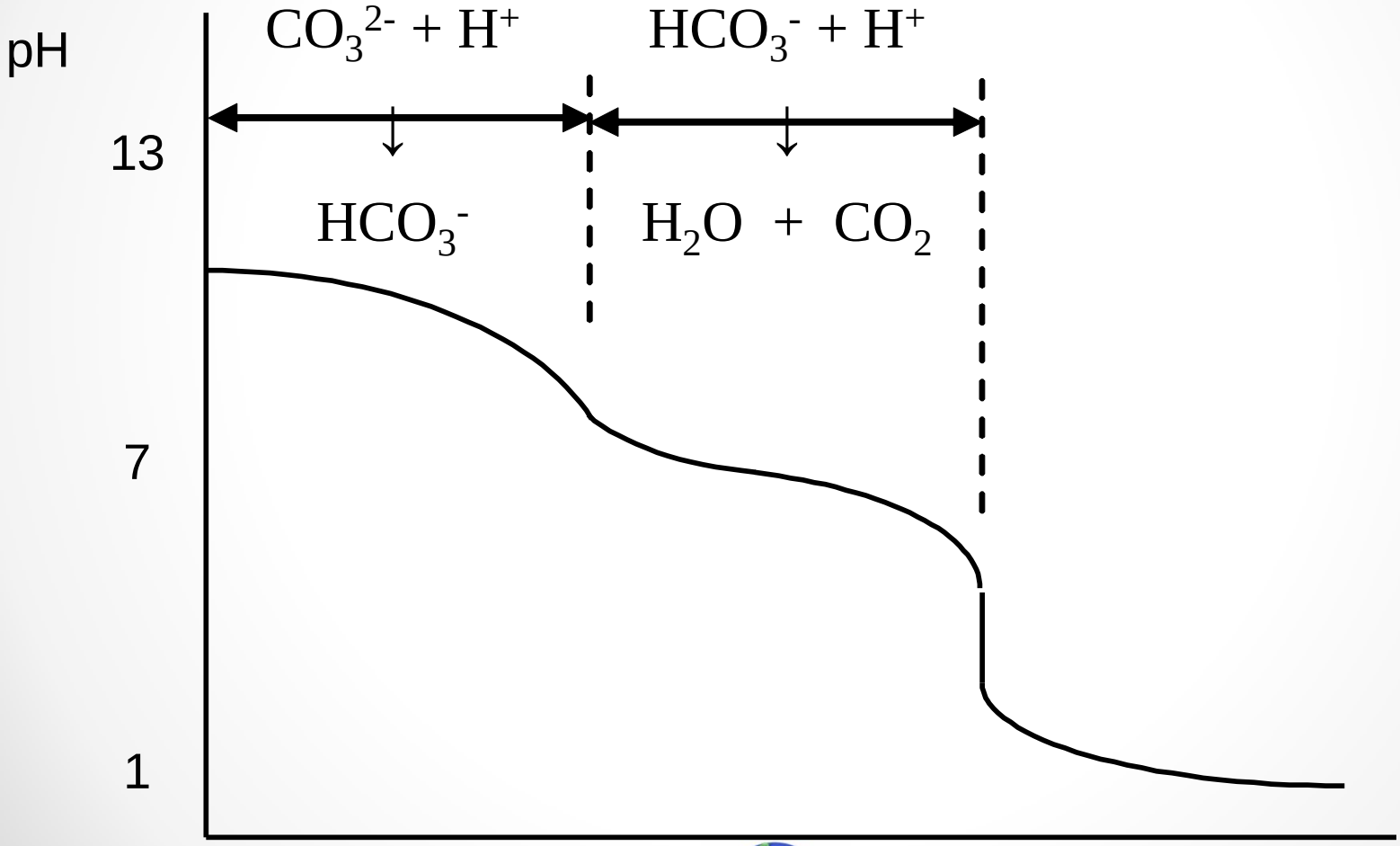
$H_2C_2O_4$ v NaOH



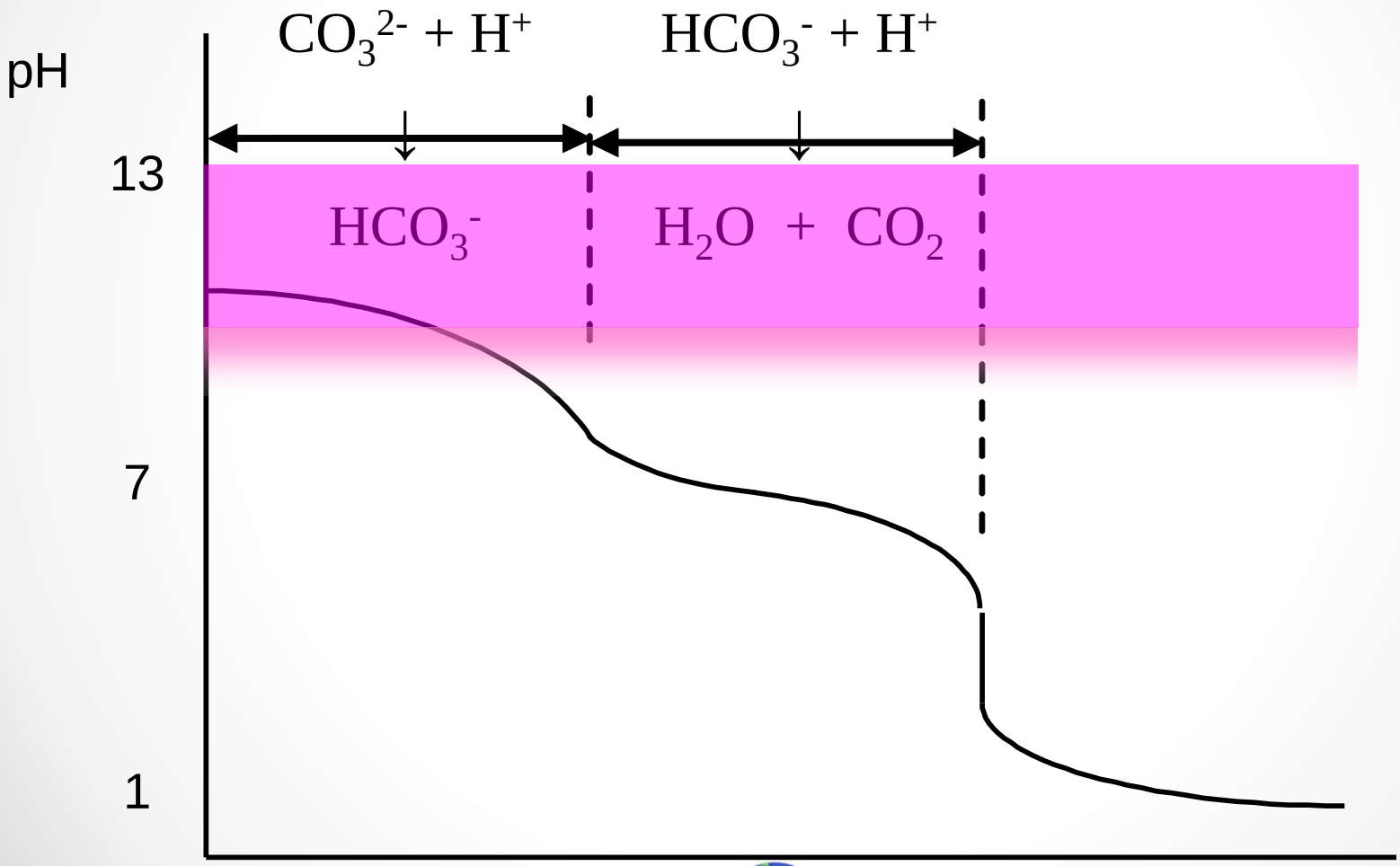
$H_2C_2O_4$ v NaOH



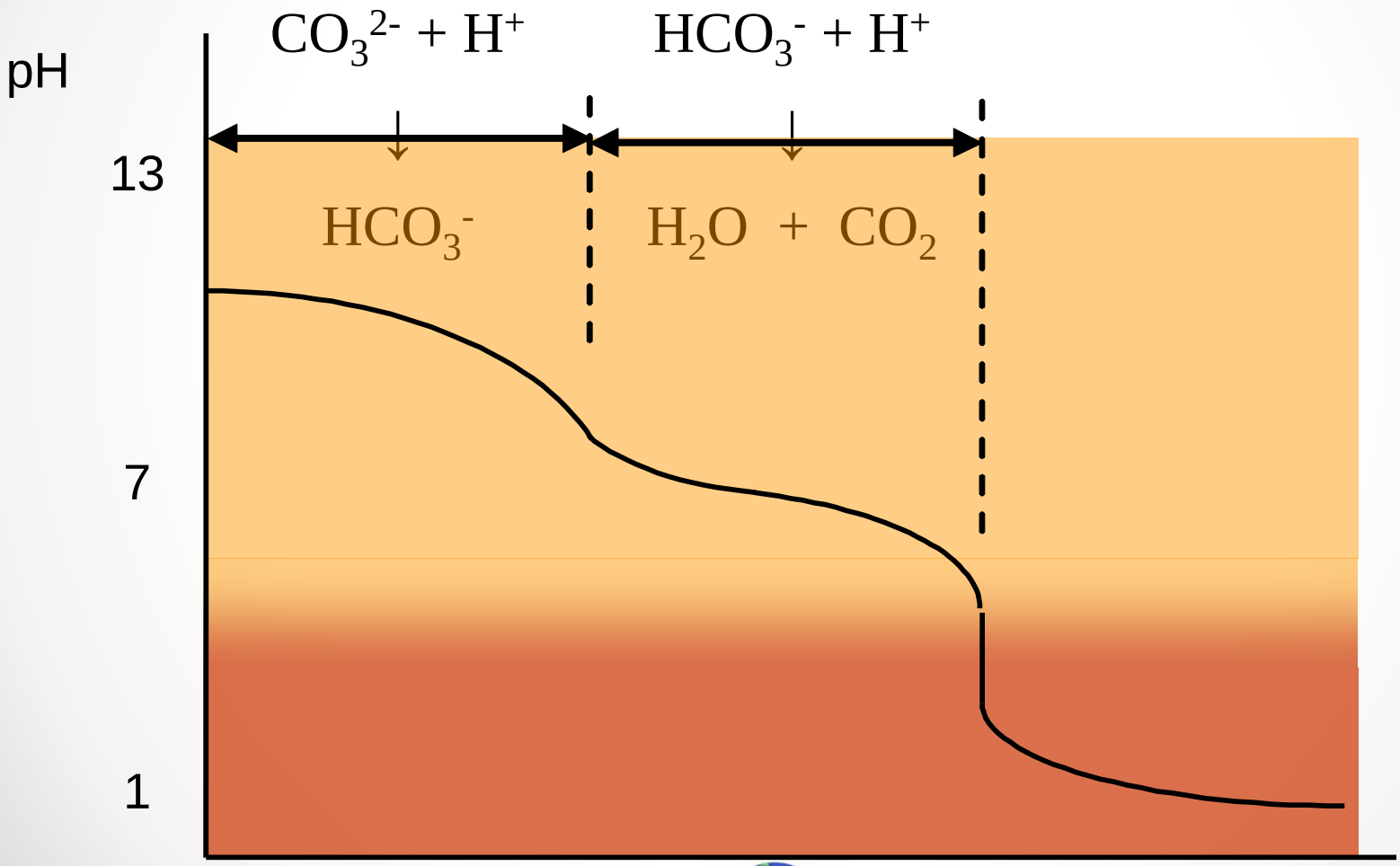
Na_2CO_3 v HCl



Na_2CO_3 v HCl



Na_2CO_3 v HCl



Behavior of Salts in Water

Table 18.8 The Behavior of Salts in Water

Salt Solution (Examples)	pH	Nature of Ions	Ion That Reacts with Water	
Neutral [NaCl, KBr, $Ba(NO_3)_2$]	7.0	Cation of strong base Anion of strong acid	None	
Acidic [NH_4Cl, NH_4NO_3, CH_3NH_3Br]	<7.0	Cation of weak base Anion of strong acid	Cation	
Acidic [$Al(NO_3)_3$, $CrCl_3$, $FeBr_3$]	<7.0	Small, highly charged cation Anion of strong acid	Cation	
Basic [CH_3COONa, KF, Na_2CO_3]	>7.0	Cation of strong base Anion of weak acid	Anion	

pH meter

- Tests the voltage of the electrolyte
- Converts the voltage to pH
- Very cheap, accurate
- Must be calibrated with a buffer solution

Salt Solutions and Relative pH

- Ions can exhibit acidic or basic properties. For example, NH_4^+ is acidic, and F^- is basic.
- Salts, being strong electrolytes, dissociate completely in aqueous solution to produce the ions which they are composed of. Therefore, salt solutions can be acidic, basic or neutral.

Acidic or Basic Salts

- A **salt** is formed between the reaction of an acid and a base. Usually, a neutral salt is formed when a strong acid and a strong base is neutralized in the reaction:
- When weak acids and bases react, the relative strength of the conjugated acid-base pair in the salt determines the pH of its solutions. The salt, or its solution, so formed can be acidic, neutral or basic.
  - A salt formed between a strong acid and a weak base is an **acid salt**, for example NH_4Cl.
  - A salt formed between a weak acid and a strong base is a **basic salt**, for example $NaCH_3COO$.
  - These salts are acidic or basic due to their acidic or basic ions.

Hydrolysis of ions

Hydrolysis refers to a reaction with water (e.g. splitting water into H^+ and OH^-)

When salts are added to water, pH can change

E.g. when Na_3PO_4 is added to water, ions form

$Na_3PO_4(aq) \rightarrow 3Na^+(aq) + PO_4^{3-}(aq)$

These ions may react with H_2O, affecting the pH

$PO_4^{3-}(aq) + H^+(aq) \leftrightarrow HPO_4^{2-}(aq)$

$Na^+(aq) + OH^-(aq) \leftrightarrow NaOH\ (aq)$

If the anion (-ve) reacts to remove lots of H^+ but the cation (+ve) removes very little OH^-, then H^+ will decrease and the solution will be basic.

The degree of hydrolysis

$PO_4^{3-}(aq) + H^+(aq) \leftrightarrow HPO_4^{2-}(aq)$

$Na^+ + OH^- \leftrightarrow NaOH$

- The problem with writing equilibria this way is we do not know the strength of the reactions
- However, if we reverse the reaction we can look up Ka and Kb values

$HPO_4^{2-} \leftrightarrow PO_4^{3-} + H^+$

$NaOH \leftrightarrow Na^+ + OH^-$

$K_a = 4.5 \times 10^{-13}$

$K_b = 55$

- Small Ka: few products; adding PO_4^{3-} = shift left
- Large Kb: mostly products; Na^+ has little affect
- Thus, adding Na_3PO_4 will cause more H^+ to be removed, resulting in a basic solution

Spectator Ions

- Note that all cations, except those of alkali and alkaline earth metals (which do not hydrolyze in water and, therefore, do not affect pH), act as weak acids in solution. (See Section 10 for a detailed explanation.)
- The relative concentrations of these ions then determine the acidic or basic properties of the solution.
- *Note :* The ions of strong acids and strong bases do *not* hydrolyze! They are so weak that they are known as **spectator ions**. Only ions of weak acids and bases hydrolyze.

Accuracy of predictions

Theoretically, using Ka and Kb values you could predict the exact pH resulting from a certain salt being added to distilled water.

However, you only need to be able to predict if a solution will be acidic, basic, or neutral.

Note: you can't judge the pH change solely on the difference between Ka and Kb. Other factors are involved (e.g. the formula of the compound and its molar mass both affect [ ])

Note: hydrolysis refers to reactions with water. Several variations for writing equilibriums exist. However, focusing on how the H^+/OH^- balance of water is affected is easiest.

Steps in determining pH

1. Write the ions that form: e.g. NH_4CN

   $\rightarrow NH_4^+ + CN^-$

2. Determine the reaction ions have with water:

$NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$ $\qquad$ $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$

$CN^- + H^+ \rightarrow HCN$ $\qquad$ $HCN \rightarrow CN^- + H^+$

3. Look up the Ka of the conjugate acid and the Kb of the conjugate base:

$$Kb = \frac{[NH_4^+][OH^-]}{[NH_3]} = 1.8 \times 10^{-5} \qquad Ka = \frac{[CN^-][H^+]}{[HCN]} = 6.2 \times 10^{-10}$$

4. Determine if more H^+ or OH^- is removed:

   More H^+ is removed, therefore BASIC

First element HYDROGEN = Acid

Binary

H and another element

Use hydro- prefix

Use –ic suffix

HCl HF HBr

H_2S HI

Oxyacid / Poly

H and 2 or more

NO prefix

If poly –ate → -ic

If poly –ite → -ous

HNO_3 H_3PO_4

H_3PO_3 H_2SO_4

Acid Nomenclature